

Title: Method, Apparatus and System for Compressing Still Image in Multipurpose
Compression Systems

5 Inventors: Hiroshi Akimoto and Igor V. Matulyak

CROSS-REFERENCE TO RELATED APPLICATION

This application claims benefit from U.S. Provisional Patent Application
No. 60/396,380, filed July 16, 2002, entitled "Method Apparatus and System for
10 Compressing Still Image in Multipurpose Compression System."

FIELD OF THE INVENTION:

The present invention relates to devices for the processing of images, and in
particular for the compression of static images to a high degree and the obtaining of a
15 restored image of high image quality. More specifically, the present invention teaches a
method of pre-processing an image, decomposition of the image using wavelet transform,
and quantizing the frequency coefficients such that images can be compressed to a high
degree and be restored with minimal information loss.

20 BACKGROUND OF THE INVENTION

Still images are an effective means for describing various subjects. Information
about the subject is accumulated in image databases. At the present time a great
multitude of types of databases have been developed that are oriented to the applications
of special methods of analysis and information processing.

25 Current digital transmitting systems have a number of advantages for image
processing in comparison with analog systems. Recently developed techniques have led
to improved methods to reduce image size. Such methods are extremely useful for digital
data storing and processing or manipulating. So it may be said that data size reduction is a
compression process. As to the architecture, it is possible now to put a complete
30 compression process into a single chip. The main objective of a compression process is to

achieve the highest compression ratio and in the same time to provide the minimum data loss that may lead to decompressed image quality degradation.

SUMMARY OF THE INVENTION

5 Systems for encoding and decoding still image of various dimensions currently exist. The methods described herein can be applied in these systems, and they may be used for Intra frame encoding as well. The current invention teaches encoding images in the following steps:

1. Image preprocessing (switch to original format),
- 10 2. Image decomposition by the wavelet transform according to features described herein (frequency block enumeration etc.),
3. Quantizing frequency coefficients using schemes described in detail herein,
- and 4. Restoring the image by performing the steps in reverse.

The method of the current invention has some significant features, which are
15 extremely important for image processing and which can really improve restored image quality and raise the compression ratio relative to methods currently used. It has been found that compression using the method of the current invention yeilds results higher than well-known worldwide standards (such as JPEG2000). Comparative data is in Tables 1, 2, 3 below shows PSNR values for JPEG2000 and the method taught by this
20 application.

The method taught herein allows the original image to be formatted during preprocessing, and the image decomposition and frequency coefficient quantizing taught herein allows the compression ration to be increased relative to currently known methods.

25 Table 1.

	Horse	Landscape
JPEG2000	31.72	25.03
Given method	31.67	26.43

Table 2.

	Fish	Squirrel
JPEG2000	35.79	29.61
Given method	35.789	30.17

Table 3.

	Robot
JPEG2000	32.06
Given method	33.236

5

BRIEF DISCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the joining of the U and V color planes together into a single plane.

FIG. 2 illustrates the Y plane after the first one-dimensional wavelet transform has been executed.

10 FIG. 3 illustrates the Y plane after the second one-dimensional wavelet transform has been executed.

FIG. 4 illustrates the enumeration of the Y plane.

FIG. 5 illustrates the enumeration of the combined UV plane.

15 FIG. 6 is an example of a pass for quantizing the frequency coefficients in the Y plane.

FIG. 7 is an example of a pass for quantizing the frequency coefficients in the combined UV plane.

FIG. 8 illustrates the construction of the Shift Array.

20

DETAILED DESCRIPTION OF THE INVENTION

The method of the current invention is executed according to the following steps:

Step 1: An image in RGB format is converted into an in image in YUV 4:4:4 format. Shown below is an example of four neighboring pixels in that format having different values for Y, U, and V.

25

$Y_1U_1V_1$	$Y_2U_2V_2$
$Y_3U_3V_3$	$Y_4U_4V_4$

Step 2: The image in YUV 4:4:4 is converted into an image in YUV 4:2:0.

Step 3: The U and V color planes are combined as illustrated in FIG. 1.

Step 4: A one-dimensional Discrete Wavelet Transform is then executed for every
5 line of the Y plane. After the transform is executed, two blocks, with multiple rows and
columns are formed such that on block (L) is for low frequencies and the other block (H)
is for high frequencies (FIG. 2).

Step 5: A one-dimensional Discrete Wavelet Transform is then executed for every
column of the obtained plane. It is the second step of Discrete Wavelet Transform.
10 Referring to FIG. 3, after the transform is executed, 4 blocks are formed as follows: (LL)
low frequency across and up, (LH) low frequency across and high frequency up, (HL)
high-frequency across and low-frequency up, (HH) high-frequency across and high-
frequency up.

At this stage the first level of two-dimensional Wavelet Transform is complete. A
15 two-dimensional Discrete Wavelet Transform is then executed for the LL block and for
each subsequent LL block until five levels of Two-dimensional Wavelet Transform have
been executed as shown in FIG. 4.

Step 6: A one-dimensional Discrete Wavelet Transform is then executed for every
line of the UV plane. After the transform is executed, two blocks having multiple rows
20 and columns are formed such that on block (L) is for low frequencies and the other block
(H) is for high frequencies (FIG. 2).

Step 7: A one-dimensional Discrete Wavelet Transform is then executed for every
column of the obtained plane. It is the second step of Discrete Wavelet Transform.
Referring to FIG. 3, after the transform is executed, 4 blocks are formed as follows: (LL)
25 low frequency across and up, (LH) low frequency across and high frequency up, (HL)
high-frequency across and low-frequency up, (HH) high-frequency across and high-
frequency up.

At this stage the first level of two-dimensional Wavelet Transform is complete. A
two-dimensional Discrete Wavelet Transform is then executed for the LL block and for
30 each subsequent LL block until five levels of Two-dimensional Wavelet Transform have
been executed as shown in FIG. 5.

The significant aspect of the current invention is that it is possible to select a filter according to image dimensions. For the SIF format a 22/14 filter is used, and for the R601 format a 5/3 filter is used. Filtering coefficients are shown in Table 4 below.

5 Table 4. Filtering coefficients.

22/14		5/3	
G	H	G	H
0.730018808		-1.7677669529e-01	
0.078814418		3.5355339059e-01	3.5355339059e-01
-0.142800426		1.0606601717e+00	7.0710678118e-01
0.018097252		3.5355339059e-01	3.5355339059e-01
0.036833941	0.648022975	-1.7677669529e-01	
-0.0093268515	0.162005743		
-0.0065812408	-0.097203451		
0.001207186	-0.02777241		
0.000975453	0.021600768		
-0.000071375	0.0029456		
-0.00006039	-0.002492395		
-0.00006039	-0.002492395		
-0.000071375	0.0029456		
0.000975453	0.021600768		
0.001207186	-0.02777241		
-0.0065812408	-0.097203451		
-0.0093268515	0.162005743		
0.036833941	0.648022975		
0.018097252			
-0.142800426			
0.078814418			
0.730018808			

Step 8: After five levels of DWT have been executed, the frequency blocks are enumerated as shown in FIGs. 4 and 5. Vertical passes for the frequency coefficients are then executed on the following blocks in order: 2, 3, 8, 9, 14, 15, 20, 21, 26, and 27.

Horizontal passes are executed on the remaining blocks. Such passes allow for effective quantization, and examples are shown in FIGs. 6 and 7.

Step 9: Every frequency coefficient is quantized as follows:

$$\Delta_i = q_i \cdot (20 + 0.5 \cdot bpp), i = 0, \dots, 31.$$

- 5 Where: i is the number of a frequency block, q_i is a value from Table 5 or Table 6 chosen according to i , and bpp is a parameter which is set in dependence of the compression ratio $0 < bpp < 255$.

Table 5.

Serial number of the frequency block (even numbers – Y frequency blocks) i	Corresponding value q_i
0	0.040000
2	0.056568
4	0.056568
6	0.080000
8	0.113137
10	0.113137
12	0.160000
14	0.226274
16	0.226274
18	0.320000
20	0.452544
22	0.452544
24	0.640000
26	0.905097
28	0.905097

30	1.280000
----	----------

Table 6.

Serial number of the frequency block (odd numbers – UV frequency blocks) i	Corresponding value q_i
1	0.000100
3	0.000100
5	0.000100
7	0.080000
9	0.113137
11	0.113137
13	0.160000
15	0.226274
17	0.226274
19	0.320000
21	0.452544
23	0.452544
25	0.640000
27	0.905097
29	0.905097
31	1.280000

Step 9.1: Every coefficient is multiplied by Δ_i .

5 if $\Delta_i \cdot \max(f_i) > 63$

or

$$\text{if } \Delta_i \cdot \min(f)_i < -63$$

so Δ_i is corrected to satisfy following conditions:

$$\Delta_i \cdot \max(f)_i < 63$$

$$\Delta_i \cdot \min(f)_i > -63.$$

- 5 Step 9.2: The obtained values are rounded to the closest integer value and recorded in one-dimensional array according to the order of the vertical and horizontal passes.

Step 10: The sequence of coefficients is quantized by the modified RLE method such that two arrays, a Data Array and Length Array, are obtained.

- 10 Step 11: Values are read from the Data Array and replaced by the corresponding value from Table 7 below.

Table 7. Replaced values.

Three-byte replaced values	One-byte replacing values
0xc140bf	0x01
0xbf40c1	0x02
0xc140c1	0x03
0xbf40bf	0x04
0xc1c0c0	0x05
0xc0c0bf	0x06
0xc0c0c1	0x07
0xbfc0c0	0x08
0xc1c0bf	0x09
0xc1c0c1	0x0a
0xbfc0c1	0x0b
0xbfc0bf	0x0c
0xbfc1bf	0x0d
0xc1bfc1	0x0e
0x400040	0x0f

Step 11.1: If a replacement value cannot be found in Table 7, a one-element shift is executed and Table 7 is rechecked for a replacement value.

Step 12: The relative displacement for values in the Length Array that are higher than 225 are placed in an additional array (Shift Array) we write the relative displacement for the values from Length Array which are higher than 255. The Shift Array is shown in FIG. 8 and its formation is discussed below.

The element with the highest value above 255 is located and its displacement relative to the first element of the Length Array is recorded in the shift array. The displacement, relative to the previous high value element, of remaining elements with values higher than 255 are then recorded in the Shift Array in order of the value.

Step 13: The Shift array is written to the end of the Length Array.

Step 14: The Length Array and Data Array values are then encoded by entropy encoding methods.

For block numbers 30 and 31 the forgoing steps are not applied. Instead, these blocks are simply entropy encoded if this is reasonable.

Step 15: The image is restored by reversing the steps above. Three byte restoration values are shown in Table 8.

Table 8. Replacing values.

One-byte replaced values	Three-byte replacing values
0x01	0xc140bf
0x02	0xbf40c1
0x03	0xc140c1
0x04	0xbf40bf
0x05	0xc1c0c0
0x06	0xc0c0bf
0x07	0xc0c0c1
0x08	0xbfc0c0
0x09	0xc1c0bf
0x0a	0xc1c0c1
0x0b	0xbfc0c1
0x0c	0xbfc0bf
0x0d	0xbfc1bf
0x0e	0xc1bfc1
0x0f	0x400040

The current invention discloses methods and procedures for compressing still images in multi-purpose compression systems. The methods and procedures disclosed in the current application can be executed or preformed in a computer, other microprocessors, programmable electronic devices or other electronic circuitry that are used for encoding images. They can be loaded into the above devices as software, hardware, or firmware. They can be implemented and programmed as discrete operations or as a part of a larger image compression strategy.

10

INDUSTRIAL APPLICABILITY

In compliance with the statute, the invention has been described in language more or less specific as to structural features. It is to be understood, however, that the invention is not limited to the specific features shown or described, since the means and

construction shown or described comprise preferred forms of putting the invention into effect. Additionally, while this invention is described in terms of being used to provide a method of compressing still images in multi-purpose compression systems, it will be readily apparent to those skilled in the art that the invention can be adapted to other uses
5 as well. The invention should not be construed as being limited to image compression and is therefore, claimed in any of its forms or modifications within the legitimate and valid scope of the appended claims, appropriately interpreted in accordance with the doctrine of equivalents.